Climate variability, extreme weather events and international migration

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CENTER ON MIGRATION, CITIZENSHIP AND DEVELOPMENT

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Editorial

The conference “Environmental Change and Migration: From Vulnerabilities to Capabilities” was the first of a new conference series on “Environmental Degradation, Conflict and Forced Migration”. It was organised by the European Science Foundation, the Bielefeld University and its Center for Interdisciplinary Research. The Center on Migration, Citizenship and Development (COMCAD), the Universities’ unit responsible for scientific content and quality of the conference, has launched a COMCAD Working Paper Series on “Environmental Degradation and Migration”. The new series intends to give conference participants the opportunity to share their research with an even broader audience.

The symposium focused on how environmental change impacts the nexus between vulnerabilities on the one hand and capabilities on the other hand, and how this relationship affects mobility patterns. Although the conference organizers chose to include all kinds of environmental change and types of migration, climate change figured prominently among the submissions to the conference. Therefore, the conference aimed to bring together the perspectives from climate change, vulnerability, and migration studies, and to draw conclusions about the political implications of the knowledge scientists currently have available. Toward that goal, the conference was structured along three pillars. The first concentrated on climate change and the vulnerability of certain regions and groups. It covered case studies as well as different approaches for making climate change projections and assessing the likelihood of vulnerability. The second pillar focused on empirical research on environmentally induced migration from a vulnerabilities perspective, but acknowledged the occasionally strong elements of capability within it. In this way, the aim was to learn about approaches and options to support existing capabilities. The third pillar was concerned with the opportunities and pitfalls of policy options in dealing with the future challenge of climate induced displacement, and with the analysis of dominant public discourses within the field.

The researchers invited represented a wide range of disciplines, including sociology, social anthropology, migration, conflict, gender and development studies, geography, political science, international law, and climate and environmental science. The conference was also well balanced in terms of geographic origin, gender, and academic status of the participants. The conference programme and full report can be found at www.esf.org/conferences/10328.

Bielefeld, February 2011 Jeanette Schade and Thomas Faist

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Abstract

Climate change and international migration flows are phenomena which attract a great deal of attention from policymakers, researchers and the general public around the globe. Are these two phenomena related? Is migration an adaptation strategy to sudden or gradual changes in climate? In this paper our aim is to investigate whether countries that are affected by climatic anomalies with respect to long-term mean experience, *ceteris paribus*, larger outmigration flows toward rich OECD countries in the period 1990-2001. Contrarily to the bulk of existing studies we use a macro approach and analyse the determinants of international bilateral migration flows employing an augmented gravity-like equation and test the relevance of climate anomalies with respect to long-term average temperature and precipitation. One important novelty in our approach is the explicit consideration in the empirical analysis of the heterogeneous nature of climate shocks, i.e. positive vs. negative variations of temperature and precipitations; non linear and threshold effects of climate shocks. Our results show that the occurrence of climate anomalies in origin countries might have heterogeneous impacts on cross-border outmigration flows depending on the type and size of the shocks and on certain socio-economic characteristics of the country (level of development, past immigration history, vulnerability of the agricultural sector). In general, countries with a higher level of development and with a growing share of irrigated agricultural land are less sensitive to climate anomalies. Interestingly we find that the existence of a network of established migrants plays a complex role. In fact, in case of certain climate shocks - such as non-extreme temperature anomalies and positive precipitation anomalies of large size - networks makes origin countries more resilient to climate shocks; hence they help affected countries to cope with climate shocks (for instance through remittance inflows as documented in other studies). We also find that in case of other climatic events - negative precipitation anomalies and extreme temperature anomalies – the existence of a large network of migrants is positively related with the subsequent size of international migration outflow. Although the analysis conducted is far from being conclusive on the complex relationship between climate change and migration, it offers interesting insights and calls for complementary methodological approaches.

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1. Introduction

The debate on climate change attracts a great deal of attention from policymakers, researchers and the general public around the globe. Although there is still a large degree of uncertainty on future climate scenario, there is a growing consensus in the scientific community that substantial changes in climatic conditions – including a growing frequency of extreme weather events - will occur.

Our knowledge on the potential socio-economic impacts of climate change is still limited not only as a consequence of uncertainty over future scenario but also as a consequence of the complex and heterogeneous behaviour of individuals and communities affected by climatic shocks. The complexity of adaptation dynamics (or resilience/vulnerability to changes) is well identified in the IPCC 2007 report: "Barriers, limits and costs of adaptation are not fully understood, partly because effective adaptation measures are highly dependent on specific geographical and climate risk factors as well as institutional, political and financial constraints" (IPCC 2007, Ch. 17).

In fact individuals might put in place different adaptation strategies in order to cope with the consequences of climate change. One of the adaptation strategies that raises a lot of concern is migration. The anxiety of governments and public opinion is not surprising given the relevant economic and social consequences of immigration flows both in sending and receiving areas/countries.

Human mobility is one among several possible adaptation strategies and it is fundamental to understand under which conditions migration is the preferred option, for which individuals within a community affected by adverse climatic conditions and which kind of migration (if any) is more likely to be observed (international or internal; temporary or permanent). Only few studies have tried to answer to these questions and quantify the links between the two phenomena, in particular as a consequence of the limited availability of reliable data on migration flows. A growing research effort has been devoted more recently to these research issues with different methodological approaches (see Piguet 2010 for a survey). Case studies and household-level surveys have contributed to our knowledge on the microlevel decisions and behaviours of individuals and communities affected by climate shocks. Although insightful, these studies give us findings that are highly heterogeneous (and often contradictory) given their unavoidable case specific nature.

In this paper we take a macro-approach and our aim is to investigate whether countries that are affected by climatic anomalies experience, ceteris paribus, larger outmigration flows toward rich OECD countries. Hence we focus on country-level data and our interest is restricted to international immigration flows (and not internal migration).[1] In particular, we analyze the role of climate change as a push factor of international migration flows. We employ a modified version of the pseudo-gravity model of Ortega and Peri (2009) in order to investigate the effects of climate shocks of different size and nature on bilateral international migration from a large sample of emerging and developing countries to OECD countries between 1990 and 2001.

Our results show that the occurrence of climate anomalies in origin countries might have heterogeneous impacts on outmigration flows depending on the type and size of climate shocks and on the socio-economic characteristics of the country (level of development, past immigration history, vulnerability of the agricultural sector). In general, countries with a lower level of development and with scarce investment in irrigation are more sensitive to climate anomalies. Interestingly we find that network of established migrants plays a complex role. In fact, in case of certain climate shocks - such as non-extreme temperature anomalies and positive precipitation anomalies of large size - networks seems to make origin countries more resilient to climate shocks (for instance through remittance inflows as documented in other studies). In the occurrence of other climatic events - negative precipitation anomalies and extreme temperature anomalies – the existence of a large network of migrants is positively related with the subsequent size of international migration outflow. Hence, established network of migrants play a complex role; they represent both a bridge to new migration flows but also a way to cope with the adverse impacts of large shocks.

The paper is organized as follows. In Chapter 2 we briefly discuss the links between climate shocks and human mobility and we outline a selective survey of relevant literature. Empirical

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[1] According to Piguet (2010) a limitation of studies employing our methodological approach is given by the so called "ecological fallacy", ie the fact that "correlations measured at the aggregated level might not hold true at the individual level". We believe that – given our research question – it is irrelevant whether or not migrants are precisely those who have been directly affected by climate shocks. On the contrary, a micro-level approach might be misleading in the sense that it is likely to underestimate the links between climate shocks and geographical relocation since by definition does not observe individuals and communities that are affected only indirectly (for instance through market dynamics, ie changes in price/factor rewards). A macro approach has the merit of being able to capture the general equilibrium effects of climate shocks on migration flows.

analysis on the role of climate anomalies as a determinant of international migration flows is presented in Chapter 3. Some conclusive remarks are reported in Chapter 4.

2. Climate and migration: what are the links?

Every year in poor and rich countries millions of individuals change their place of residence (see SOPEMI 2009 and 2008 for recent data on international migration flows). Human mobility might assume very different forms: within or across countries, voluntary versus forced, temporary versus permanent, legal or illegal. The common trigger in all cases has to be found in changes in individual/ family conditions and / or changes in economic and social opportunities in origin and destination locations.

Can we consider changes in climatic conditions as push (or pull) factors of human migration? While the answer is certainly positive, the definition of the exact nature and a quantitative assessment of the links between climate change and migration is a complex task. Whether a change in climatic conditions in a specific location is sufficient enough to induce individuals to geographically relocate will depend on multiple factors such as the nature of climatic shocks, characteristics of the population affected and the vulnerability of the economic and social systems (including the ability to undertake alternative coping strategies).

Firstly, the vulnerability of individuals to climate change will depend, *ceteris paribus*, on the magnitude and types of climate anomalies. Economic systems – and individuals within them – might have different degrees of vulnerability to different kind of climatic shocks (temperatures, precipitations, extreme events). For instance, extreme climatic events such as droughts, floods or hurricanes are likely to have severe impacts - at least in the short run - on the economic resources of a given community and, as a consequence, might severely limit the adoption of adaptation strategies alternative to migration. On the other hand, gradual changes such as the reduction of precipitation over time might have a smaller impact on the well being of a community if individuals are able to adjust their productive strategies over time (for instance through investments in irrigation systems or use of drought resistant agricultural varieties).

The economic consequences of climatic changes might also be highly non-linear: the increase in temperature or reduced precipitations might have trivial or no effects up to a certain threshold and dramatically increase when such limit is crossed. An interesting work by le Blanc and Perez (2008), using GIS data on rainfall and population density in Sub-Saharan

Africa for year 2000, shows that water scarcity constraints human density only below a certain threshold[2]. This result suggests that vulnerability of population to water stress (caused by climatic or population pressures) depends upon the level of water resources.

Another aspect that should be considered is the asymmetric impacts that climate anomalies might have across the affected population. While some individuals or industries might be negatively affected, others might benefit (both as a direct consequences of such changes or indirect effects taking place through market mechanisms). As recent evidence on adaptation strategies in a sample of African countries shows, counteracting effects might be also present in highly vulnerable communities. Analysis based on micro-level data on a sample of African farmers point out that higher annual temperatures are associated with positive variation of net revenues for livestock owners and negative variations of net revenues from crop production (CEEPA 2008). If climate change affects asymmetrically the productivity or the endowment of different factors of production (labour, capital, land) also the structure of production and factors' rewards will change in a asymmetric way.

The choice on whether to undertake or not adaptation strategies (including outmigration) will also depend on the perceived duration of climate anomalies (ad its consequences). Given that migration is a costly adaptation strategy – in particular migration across borders – if individuals perceive changes as transitory they might decide to adopt alternative strategies (or adopt a "wait and see" strategy and post-pone the migration decision) even if the climatic changes are highly destructive. On the contrary, if changes are perceived as permanent they might be more inclined to opt for costly but resolving adaptation strategies. Halliday (2006) provides evidence which might support this idea. Using data on a panel of rural household from El Salvador the author finds that while adverse agricultural shocks (harvest and livestock loss) increase migration toward the US, the damages caused by the 2001 earthquake are associated to a reduced probability of outmigration. The transitory nature of the latter shock might be a possible explanation for such heterogeneous reaction.[3]

[2] The authors finds that above a mean annual runoff of 900mm rainfall and human density are not correlated. Note that, as the authors point out, sixty percent of the population in Africa lives in zones with mean annual runoffs of less that 300mm.

[3] The author suggests another possible explanation associated to the different labor market effects of the shocks. "One explanation is that the earthquakes created exigencies in El Salvador that increased the incentives for families to retain labor at home" (page 895, Halliday 2006). The two explanations need not be substitute but they go in the same direction: in fact if the destructive event is perceived to be permanent then the incentive for families to

In order to analyse the effects of climate anomalies on migration it is important to distinguish direct effects from indirect channels which produce their effects on migration flows via other push and pull factors. In Figure 2.1, we report a schematic representation. Changes in climatic conditions could have both *direct effects* as push factors of migration flows when the possibility of human survival in the "new" environment are reduced (for instance because of unsustainable water supplies) or *indirect effects* through market forces.[4] Migration might be induced by changes in quality of life[5], economic opportunities or a combination of both set of factors. If climate change affects the endowment and efficiency of productive factors, then both factors' prices and prices of final goods and services would also change.

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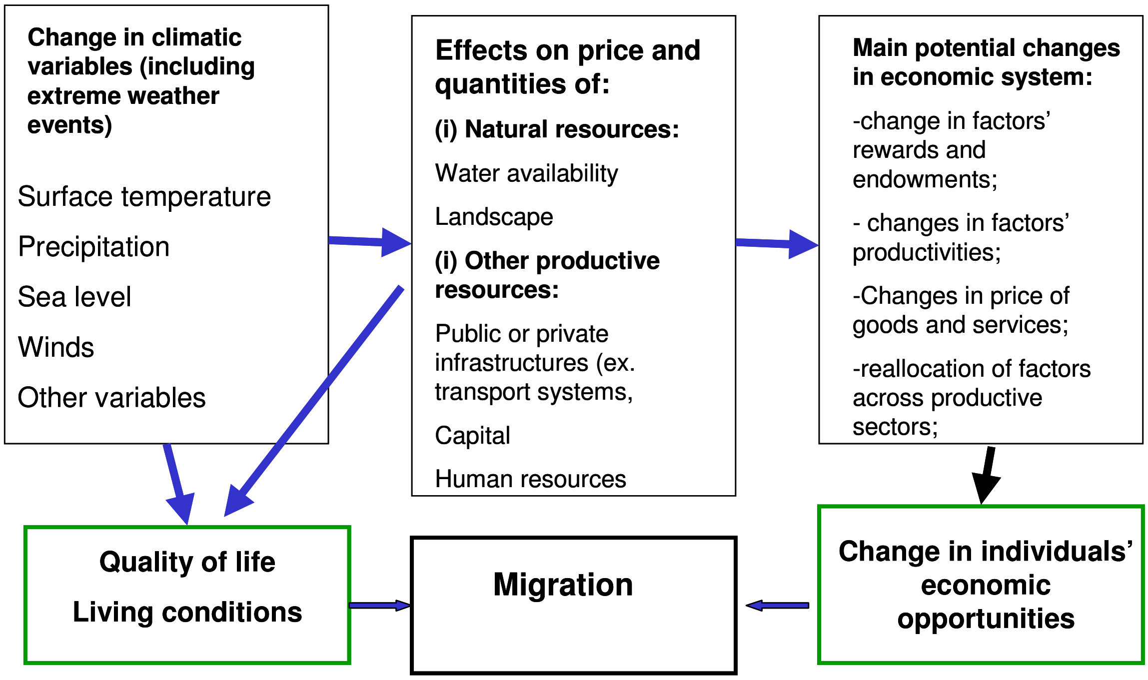
retain labor at home would be weak.

[4] Indirect changes can also occur through non market forces. Environmental degradation has often been one important factor behind social conflicts (see the interesting work by Reuveny 2007). Also in these cases, it is often possible to track back the occurrence of social conflict and wars to the economic and re-distributive consequences of climate shocks.

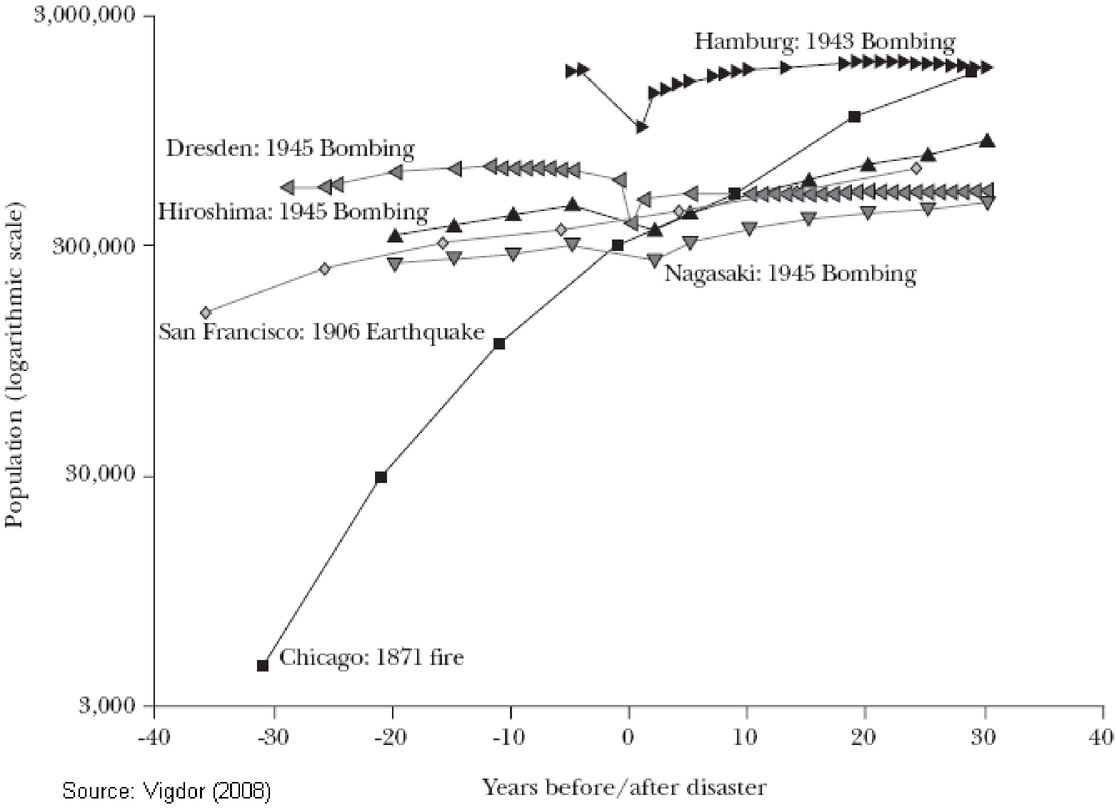
[5] There is a rich literature on the role of climatic amenities in affecting migration (or population growth in general). Cebula (2005) finds that gross state in-migration in the US over the period 1999-2002 is an increasing function of warmer temperatures, sunshine and recreation possibilities. Cheshire and Magrini (2005) show that urban population growth in EU countries is positively related to good climate but spatial variations seems to matter only within national borders: individuals do not respond to differences in weather conditions by cross-border relocation.

Figure 2.1 – Climate changes and migration: a map of direct and indirect links



Economic systems might be highly resilient to climate-related shocks. In particular in urban areas where agglomeration forces are strong and exert a centripetal force on productive factors (including labour). The strength of agglomeration externalities can be appreciated by looking at how cities recover from devastating shocks as reported in Figure 2.2, taken from Vigdor (2008). In the figure, population trend pre- and post-shocks are reported for seven cities hit, in different times, by natural or man-made disasters of high magnitude. Cities that were growing before the event in all cases considered by Vigdor continued their positive trend also in the aftermath of disasters (even in the case of the extremely strong earthquake of San Francisco which left homeless more than half of the population. The same pattern is observed in the case of shocks with more long lasting effects on environmental conditions (such as radiations from the atomic bombs of Hiroshima and Nagasaki). In many cases the adjustment was not particularly quick, and in the case of Dresden a complete rebound to pre-shock levels is not observed. Davies and Weinstein (2002) use the "exogenous" events of bombing of Japanese cities during WWI in order to assess competing theory of urban growth. In their analysis they find a highly persistent relative structure of the urban system with an almost complete rebound to pre-bombing equilibrium by 1960s. A similar study by Bosker et al (2008) on bombing of German cities in WWI finds evidence of recovering in absolute term but also some non-transitory effects on relative city size (population size relative to cities not, or less, affected by the shocks).

Figure 2.2 – Disasters and the persistence of City Population trends



Source: Vigdor (2008)

These examples suggest that urban externalities might imply high resilience to (climatic or other) shocks. A key role in determining the population pattern is played by the degree of factors' mobility. Only when factors (capital and / or labour) are geographically mobile, also small changes in prices can drive large shifts in the geography of production.[6]

Different levels of resilience – for instance between urban and rural areas – imply that the ability to undertake different adaptation strategies is highly heterogeneous across communities. Qualitative analysis undertaken using ethnographic methods suggests that the degree of resilience – and hence the choice of migration as an adaptation strategy – is highly heterogeneous also across individuals. Reuveny (2007) argues that "people can adapt to envi-

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[6] Further insights can be gained by analysing the potential effects of climatic shocks within the so-called New Economic Geography (NEG) literature. The NEG was pioneered by the Nobel prize winner Paul Krugman in 1991 and further developed by other scholars (among others Richard Baldwin, Tony Venables, Ian Wooton, Gianmarco Ottaviano, Jaques Thisse, Masahita Fujita). For a survey see Baldwin R., Forslid R., Martin P., Ottaviano G. and F. Robert-Nicoud (2003), Economic Geography and Public Policy. Princeton University Press, Princeton NJ.

ronmental problem in three ways: stay in place and do nothing, accepting the costs; stay in place and mitigate the changes; or leave affected areas" (page 657). The cost and benefits of each option will largely depend on individual's actual resources (which might be affected or not by environmental changes), future expectations and the (partly-exogenous) institutional framework within which the environmental shock takes place. Individuals and households with a larger endowment of resources (financial assets, land and other capital goods, human capital, social capital or "relationship capital"[7]) are more likely to undertake adaptation strategies rather than do nothing but it is not necessarily the migration strategy the one that will be selected. For instance, individuals with large endowments of immobile capital (such as land or real estates) are probably less mobile than individuals with only a limited amount of capital or who derive their income only from labour. Individuals with high level of human capital might have a relative low cost of access to new technologies or productive processes which overcome the negative consequences of climate change.

One particular form of "relationship capital" is the possibility for the individual to rely on a network of family and friends who reside in other locations (migration networks). The effect of this form of capital on migration propensities might be ambiguous: in fact while, on one hand, the network might exercise a strong pull effects reducing migration costs, on the other hand external support (for instance in the form of remittances) might facilitate the adoption of other coping strategies. Yang and Choi (2007) using household level data from the Philippines find that remittance flows increase as a consequence of rainfall shocks (replacing up to 60% of the decline in household income). Findley (1994) in a study on migration from rural Mali after the severe 1983-85 drought finds no evidence of increased international migration and Findley and Sow (1998) find that food deficit in rural households in Mali were compensated by remittances from migrants in France. These findings confirm the role of remittances (a consequence of established networks) as an insurance mechanism against income shocks. On the opposite side, the studies by McLeman on the drought in Oklahoma during the 1930s suggest that networks played a role of "bridge" and favoured the adoption of migration as a coping strategy (McLeman 2006; McLeman and Smit 2006).

Another important element that might play a significant role in the nexus between climate change and migration is public policy responses both before - such as pre-emptive measures and insurance mechanisms that limit the vulnerability to or the consequences of shocks

[7] Here we define relationship capital as the potential economic value derived from individuals' (weak and strong) ties with other individuals who reside in the same location or in other locations not affected by climatic changes.

– and after the environmental damages occur (emergency help, financial subsidies and aid, recovery plans etc.). Good governance will generally limit the extent of damages and reduce the number of individuals who will adopt migration strategies. An important role is often played by international support. According to a recent paper by Collier and Goderis (2009) the level of international aid mitigates the effects of negative shocks but they also find that donors do not re-distribute aid overtime toward shock-prone countries. By looking at the consequences of a specific climatic shock, hurricanes, Yang (2008)[8] finds that a greater exposure to these events leads, in developing countries, to a large increase in foreign aid. In his study, the author considers different types of international financial flows to developing countries in the aftermath of hurricanes: official development assistance (ODA), foreign direct investments, remittances, lending from multilateral institutions, portfolio investment and bank and trade-related lending. For the poorer countries within his sample, total financial inflows in the 3-years following the extreme climatic event represent approximately three-fourths of estimated damages. As mentioned above an important role in poorer country is played by remittances.

In general, institutions affect the efficiency of shock-absorption mechanisms both before and after the occurrence of climatic changes. According to Reuveny (2007), the role of the US federal government was fundamental in limiting out-migration from the US Great Plains in the 1930s after a series of very severe drought. In fact, the policymakers gave substantial financial and technological assistance to the farmers who decided to stay in the affected areas.

2.1 Migration: where?

The list of factors outlined above gives an idea on the complexity of the nexus between climate shocks and migration. Another related issue that should be considered is the following: *if changes in climatic conditions are strong enough to trigger human mobility, which kind of moves are we likely to observe?* Relocation strategies might be highly different according to which individuals are affected and to which environmental episodes we observe. For those individuals who lack the financial resources to finance a costly international move, or for those communities who have a weak or inexistent network of established migrants in foreign

[8] An interesting innovation of Yang (2008) is the use of a time-varying storm index which allows to take into account the magnitude of the shocks (proxied by the fraction of the country population affected by the event).

locations, migration is likely to be of short distances and within the country. Cross-border migration will take place if this option, compared to other adaptation strategies, is not too costly. This might happen when the country affected by adverse climatic shocks is geographically, culturally or socially close to potential receiving countries.[9]

The dominance in terms of magnitude of internal migration flows over international flows is a stylised fact in migration literature on which there is unanimous consensus. Whatever is the determinant of migration, individuals are more sensitive to differentials in socio-economic conditions within countries that between them. The existing evidence confirms that this holds true also for climatic changes. In Table 2.1 we report information on 38 environmental episodes which have caused, according to Reuveny (2007), out-migration flows (as a primary factor or with other concomitant push factors). In most cases only internal relocation (see column 4) takes place and often from rural agricultural areas to urban areas. International migration flows of certain relevance are observed less frequently and are almost always in border countries (short-distance or toward countries with pre-existing political, ethno linguistic or cultural ties).

Barrios et al (2006) investigate the role of climate change on rural – urban migration in a panel of 78 countries over the period 1960-90. Their results outline a positive and statistically significant relationship between urbanization and climate change, proxied as changes of annual rainfall from the long-term mean, for Sub-Saharan Africa. No significant results are found for other developing countries suggesting that the strength of the link between climate change and migration is larger for those communities where agriculture is more vulnerable to shortage in rainfall.

The non-exhaustive list of factors outlined above which mediate the links between climatic changes and migration as an adaptation strategy implies that social scientists need to use multiple and complementary research strategies to broaden our knowledge on this important issue: from case studies on individuals and households in community affected by adverse climatic events to econometric analysis on international migration flows (such as the present study).

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[9] Migration might also differ in terms of duration. The move might be temporary (if, for instance the climatic shock does not produce long-lasting effects) or permanent. Analysing a sample of irregular migrants crossing Italian borders in 2003, Coniglio et al (2009) finds that individuals experiencing adverse climatic shocks or natural disaster in the village of origin are more likely to return home that individuals experiencing social conflicts.

In his survey of recent empirical analysis on the links between climate change and migration Piguet (2010) discusses relative strengths and limits of alternative methodological approaches[10]. In discussing the limits of empirical approaches similar to our study which employ multivariate methods using geographical areas as unit of analysis (ecological inference based on area characteristics) the author mentions two aspects. Firstly, the paucity and quality of environmental indicators used. In fact most studies employ rather rough and unsophisticated indicators of environmental change (such as past level or anomalies in rainfall). In what follows we consider more refined environmental variables which aim at separating climate anomalies of different size and nature (for example positive versus negative precipitation anomalies or non linear effects of anomalies). The second limit emphasized by Piguet (2010) is the so-called 'ecological fallacy' due to the fact that "correlations measured at the aggregate level might not hold true at individual level" (page 518, Piguet 2010). In our analysis the unit of observation is the individual country and although we acknowledge the fact that the impact of climate shocks might differ substantially across subgroups (and even that those who migrate might be different from those directly affected by climate shocks) we are specifically interested in aggregate net effects and not on individuals' and communities behaviour.

Bearing in mind the complex links outlined in this section, we present in the following part the results of an empirical analysis on the role of (observed) climatic changes on international migration flows.

Table 2.1 – Environmental migration episodes reported in Reuveny (2007)

Period	Origin	Destination	Cross border flows	Environmental push factors	Other push factors	Number of migrants*
1970s - 1990s	1. Bangladesh (rural areas, coastal areas, islands)	Bangladesh (Chittagong Hill Tracts)		Droughts, water scarcity, floods, storms, erosion, desertification	Overpopulation, underdevelopment, government migration incentives	600,000
1984 - 1985	2. Ethiopia: (a) central/northern; (b) Awash river basin-Afar,	Ethiopia: (a) southwest, west; (b) Wollo region		Drought, famine, forest fires, locust invasion	Underdevelopment, overpopulation, government promotes cotton/sugar, overgrazing	600,000
early 1990s	3. Rwanda (rural south, center)	Rwanda (north), Zaire	yes	Arable land/water scarcity, land degradation, deforestation	Overpopulation, food scarcity, civil war, underdevelopment, government aid in north	1.7 Million
1960s -	4. Mexico and Southern Guate-	Mexico (eastern, Chiapas)	yes	Land degradation, deforestation, land pressure	Persecution, civil war in Guatemala, Mexican government	280,000

[10] The author classifies the existing empirical evidence in 7 different types: ecological inference based on area characteristics (to which the present study belongs), individual sample surveys, time series, multilevel analysis, agent based modelling and qualitative/ethnographic methods.

1990s	mala				resettlement policy,unequal land distribution, overpopulation	
1950s - current	5. Bangladesh (various regions)	India, West Bengal, Assam, Tripura	yes	Droughts, water/land/ food scarcity, land erosion, storms, salt intrusion	India's diversion of Ganges River, failure to share river water, overpopulation	12-17 Million
1950s - 1980s	6. El Salvador	Honduras up to the late 1960s, then US	yes	Deforestation, land degradation, arable land/water scarcity	Wealth disparity, skewed land-tenure, poverty, overpopulation, repression	300,000 to Honduras, 500,000 to US
1960s - 1980s	7. Ethiopia/ Eritrea	Southern Sudan	yes	Droughts, famines	Underdevelopment, Eritrean secession, war	1.1 Million
1980s - 1990s	8. Mauritania,	Senegal, Senegal River Valley	yes	Drought, soil erosion, desertification, deforestation, water scarcity	Moors-African enmity, interstate war, Senegal river dam raises land values and stakes, population growth	69,000
late 1970s	9. Somalia	Somalia - Ethiopia border region (Ogaden)	yes	Arable/grazing land degradation, water scarcity	Underdevelopment, population growth, interstate war	400,000
1970s - 1990s	10. Haiti (north)	Rural hillsides, l'Artibonite region, cities, Dominican Republic, US	yes	Deforestation, land scarcity/degradation, erosion	Poverty, inequality, high density, repression	1.3 Million
1970s - 1990s	11. Philippines (lowlands)	Philippines (center, uplands)		Arable land/water scarcity, deforestation, floods, slides, drought, land degradation	Overpopulation, land/wealth disparity, vague property rights, unemployment, underdevelopment	4.3 Million
1970s - 1980s	12. South Africa (black areas)	South Africa (urban centers)		Land degradation, deforestation, subsistence crisis, water scarcity	Repression, poverty, poor infrastructure, African unemployment, overpopulation	Up to 750,000 per year
late 1960s - 1980s	13. Sahel (rural areas)	Sahel (urban regions, neighboring coastal states)	yes	Droughts, famines, land scarcity	Inflation, underdevelopment, overgrazing	10 Million
1960s - current	14. Brazil (northeast)	Brazil (central and southern Amazon region)		Droughts, land degradation, water scarcity, deforestation	Overpopulation, poverty, land disparity, government subsidizes settlers, vague property rights	8 Million
1970s - 1980s	15. Sudan (north, south, west)	Sudan (Khartoum, Central, Kordofan, east)		Droughts, famine, desertification, deforestation, erosion	Civil war, underdevelopment, policies against small farms and pastoralism, population growth	3.5 - 4 Million by early 1990
1930s	16. US (Great Plains)	US (other regions)		Droughts, sand storms, land degradation	Great Depression, overplowing/grazing	2.5 Million
late 1970s	17. Ethiopia	Ethiopia - Somalia border region, Ogaden	yes	Grazing/arable land degradation, deforestation	Overpopulation, Ogaden War, land disparity, underdevelopment	450,000
1970s - 1990s	18. Nigeria (Jos Plateau)	Nigeria (urban areas, intra-regional)		Soil/water/air pollution, silted rivers, land scarcity/degradation	Tin-mining, poverty, unemployment, high population density/growth	n/a
1980s - 1990s	19. Pakistan	Pakistan (urban areas, especially Karachi and Islamabad)		Water scarcity, deforestation, pollution, floods, land degradation	Population growth, unequal access to resources, poverty, unemployment, unclear land-tenure	n/a
1970s - 1990s	20. Bangladesh (rural areas)	Bangladesh, urban centers		Droughts, storms, floods, water scarcity	Overpopulation, rural poverty	n/a
1980s - 1990s	21. China (primarily Gansu and Ningxia)	China (urban centers)		Floods, land degradation, desertification, water scarcity	Mountainous terrain, poverty, malnutrition, government incentives	20 - 30 Million
1970s - 1990s	22. Ecuador (highlands, southern region)	Ecuador (northern Amazon)		Droughts, deforestation, land degradation, water scarcity	Underdevelopment, constructing oil pipelines in Amazon region	n/a
1995 - 2000	23. North Korea	China (urban centers)	yes	Floods, tidal waves, droughts, land degradation, deforestation	Failure of collective farming policy, lack of infrastructure, poverty	300,000 - 400,000
late 1980s - mid 1990s	24. Somalia	Somalia-Ogaden, Kenya, Ethiopia, Djibouti	yes	Drought, erosion, deforestation	Civil war in Somalia, population growth, overgrazing	2.8 Million
1950 - 1980s	25. Guatemala (rural areas)	Guatemala (north Peten	yes	Land degradation, deforestation, floods, river sedimenta-	Overpopulation, land inequality, underdevelopment, gov-	100,000

		region, urban centers, eastern lowlands, Pacific Coast), US		tion, water scarcity	ernment promoting export crops, insurgency	
1940s - 1980s	26. Dominican Republic (Las Ayumas)	Dominican Republic (Santiago's urban center)		Deforestation, land degradation	Coffee price rise stimulates deforestation to grow coffee, poverty	Several tens of thousands
1931 - 1939	27. Canada (Great Plains)	Canada (other regions, urban areas)		Droughts, sand storms, land degradation	Great Depression, overplowing/grazing	300,000
	28. Mexico (rural areas, Oaxaca)	Mexico (urban centers), US	yes	Drought, land degradation, water scarcity, deforestation	Underdevelopment, inequality, population growth	600,000 - 900,000 annually
1960s - 1990s	29. Kenya (Western, Northern)	Kenya (Rift Valley,some remain in West, urban centers)		Drought, land degradation, land scarcity, famine	Overpopulation, ethnic strife, inequality, unemployment	150,000 - 200,000
1970s - 2000	30. Uzbekistan, Kazakstan, Aral Sea,	Within region or adjacent regions	yes	Pollution, salinization, dust storms, water scarcity, sea desertification	Unemployment, underdevelopment, ethnic factor, water scarcity	65,000 - 100,000 annually
1990s	31. Caspian Sea region, Kalmykia	Russia, neighboring regions	yes	Inundation, floods, land scarcity	Ethnic pull factor, unemployment, underdevelopment	2200 - 8100 annually
	32. Russia (Kola Peninsula)	Russia (various regions)		Air pollution	Poor healthcare, social problems	5% of Population
1960s - 2000s	33. Burkina Faso (Mossi Plateau)	Burkina Faso (south, east)		Drought	Underdevelopment, population pressures	n/a
1978 - 1983	34. India (west Rajasthan, East India)	India (Haryana, Madhya Pradesh, Madras)		Drought	Underdevelopment	n/a
1980s - current	35. Zimbabwe (Southern lowlands)	Zimbabwe (highlands)		Drought	Unclear property rights, overgrazing, poverty, seasonal movement	n/a
1980s - 1990s	36. Thailand (northeast)	Thailand (other rural, areas, urban centers)		Deforestation, land scarcity/degradation	Underdevelopment	n/a
1990s	37. Russia (Arctic region)	Russia (urban centers), other CIS countries	yes	Extreme weather	Socioeconomic decline	70,000
1950s - 1990s	38. Tanzania (Southern and northeast regions)	Tanzania (Usangu Plains)		Land scarcity/ degradation	Overpopulation, poverty, government promotes commercial agriculture	84,000

3. Empirical analysis

In this section we investigate the determinants of international bilateral migration flows from a sample of 165 origin countries toward 25 OECD countries in the period 1990-2001[11]. Our main aim is to test the relevance of climate shocks in the origin countries as a push factor of bilateral migration flows. We follow a methodological approach similar to Ortega and Peri

[11] We use unbalanced data for the sending/origin countries reported in Appendix A. To the best of our knowledge comprehensive dataset on bilateral migration flows which include also South-South migration (i.e. migration between and within less developed and emerging countries) are not available.

(2009)[12] and use a pseudo-gravity empirical specification. Like in their model the dependent variable is the total size of bilateral migration flows. In particular, we estimate the following specification:

$$ln(M_{ijt}) = \beta_0 + \beta_1 \boldsymbol{X}_{i,t-1} + \beta_2 \boldsymbol{Z}_{ij,t-1} + \beta_3\ (\boldsymbol{ClimateShocks_{i,t-n}}) + D_i + D_j + D_{jt} + e_{ijt} \qquad (1)$$

where M_{ijt} is migration flow from origin country *i* to destination country *j* at time *t*[13]*.* We introduce a set of push factors operating in the country of origin $\boldsymbol{X}_i$ (*GDP per capita, change in employment rate* and the *change in the surface of irrigated land* occurred in the year before) and our main covariates of interest, $ClimateShocks_{j(t-n)}$ which represent a vector of *changes of climatic conditions* in origin country *i.* In addition we control for a set of bilateral variables $\boldsymbol{Z}_{ij,t-1}$ which greatly affect bilateral migration flows such as *geographical distance* between country *i* and *j*, the log of the *bilateral stock of migrants* from origin country *i* in destination country *j*, a dummy equals one if the pair of countries share a *common language*. In order to control for time-varying pull factors related to economic, social and policy changes in destination countries we introduce in the empirical specification a set of country-of-destination-by-time fixed effects (D_{jt}). These set of dummies will hence absorb any effects specific to the OECD destination countries. The specification includes also country of origin and destination fixed effects in order to control for time-unvarying characteristics.

The non-climatic and climatic covariates used in the regression analysis are described in Appendix B. With respect to the former, we expect a negative effect of GDP per capita and employment rate change on bilateral migration; both variables proxies for economic opportunities in the origin country. Our a priori expectation on the effect of a *change in the surface of irrigated land* is to observe a negative relationship with outmigration. We also expect, as in existing studies, that *geographical distance* is negatively related with bilateral flows between origin and destination countries. On the contrary, we expect that a common language and a dense network of already established migrants, by reducing the cost of migration and increasing the number and value of opportunities in the destination country, are positively associated with bilateral flows.

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[12] Differently from their work, our main focus is on push factors (in particular climate anomalies) rather that pull factors such as immigration policy changes.

[13] When the bilateral flow is zero we add 1 to it before taking the log.

Our climatic variables are based on data from Mitchell et al (2003) who provide detailed information on average precipitation and temperature at country-level for the period 1901-2000[14]. For each origin country in the dataset we computed a rich set of variables which measure climate anomalies – in temperature and precipitation - with respect to the country mean during the period 1961-90[15]. An important novelty of our approach is the explicit consideration in the empirical analysis of the heterogeneous nature of climate shocks (positive vs. negative variations of temperature and precipitations; non linear effects of climate anomalies; threshold effects of climatic anomalies; repeated vs. isolated events etc.).[16] In particular, we test for the relevance of the following climatic variables as push factors of international migration flows:

(i) annual yearly absolute level of precipitation and temperature;

(ii) precipitation and temperature anomalies with respect to countries' long-term values (both absolute value - in millimeters and Celsius degree respectively - and percentage value);

(iii) positive and negative anomalies;

(iv) squared values of anomalies (in order to detect non linear effects);

(v) persistent anomalies (cumulated values of anomalies in the previous 3 and 5 years);

(vi) extreme values of climate anomalies.

Our aim is to overcome the unsatisfactory identification of climatic shocks of previous studies (see for instance Barrios et al 2006) which is particularly unfitting in the light of results stemming from a large number of case studies. In fact, as discussed above, the existing qualitative evidence emphasize the highly heterogeneous effects on local communities of climate shocks of different nature.

[14] TYN CY 1.1 database, Mitchell et al. (2003). Available at: www.cru.uea.ac.uk/~timm/cty/obs/TYN_CY_1_1.html

[15] According to the authors the accuracy of the data is the highest for the time interval 1961-90.

[16] Some data limitations are unavoidable, in particular we are aware that using yearly data aggregated at the country-level might mask high intra-borders variations and seasonal shifts. As other studies have pointed out (Moore and Reuveny 2009; Piguet 2010) the complexity of the relationship between climate and migration implies that multiple empirical research designs are necessary since a single approach cannot provide compelling answers.

The starting point of our analysis is the parsimonious baseline model of bilateral migration flows reported in the first column of Table 3.1.

Table 3.1 – Climate anomalies and international migration: baseline estimations

Dependent variable: Bilateral migration flows ij (in log)	**Baseline**	**(1)** PREC	**(2)** PREC	**(3)** PREC	**(1)** TEMP	**(2)** TEMP	**(3)** TEMP	**(1)** PREC/ TEMP	**(2)** PREC/ TEMP
GDP per capita i (lag 1; ln)	-0.211**	-0.33***	-0.34***	-0.33***	-0.32***	-0.33***	-0.32***	-0.34***	-0.33***
	(0.0759)	(0.0862)	(0.0867)	(0.0925)	(0.0901)	(0.0903)	(0.0895)	(0.0870)	(0.0921)
Employment rate difference ij (lag 1)	0.024***	0.0234*	0.0238*	0.0246*	0.0244*	0.0240*	0.0236*	0.0229*	0.0235*
	(0.00698)	(0.013)	(0.0134)	(0.0133)	(0.0132)	(0.0131)	(0.0137)	(0.0132)	(0.0137)
Irrigated land % i (change lag2 - lag1)	-0.17***	-0.0124	-0.0226	-0.0213	-0.0175	-0.0196	-0.0140	-0.0281	-0.0178
	(0.0575)	(0.128)	(0.127)	(0.128)	(0.125)	(0.126)	(0.125)	(0.128)	(0.125)
Network migrants ij (1990s; ln)	0.519***	0.608***	0.608***	0.608***	0.608***	0.608***	0.608***	0.608***	0.608***
	(0.0314)	(0.0374)	(0.0374)	(0.0373)	(0.0373)	(0.0373)	(0.0373)	(0.0373)	(0.0373)
Distance ij (ln)	-0.51***	-0.356**	-0.356**	-0.356**	-0.356**	-0.356**	-0.356**	-0.355**	-0.356**
	(0.139)	(0.148)	(0.148)	(0.148)	(0.148)	(0.148)	(0.148)	(0.148)	(0.148)
Common language (dummy)	0.637***	0.511***	0.511***	0.511***	0.511***	0.511***	0.511***	0.511***	0.511***
	(0.155)	(0.146)	(0.146)	(0.146)	(0.146)	(0.146)	(0.146)	(0.146)	(0.146)
Precipitation (mean past 3years; absolute value in mm)		-0.00024							
		(0.00022)							
Precipitation anomalies (mean past 3years; absolute value in mm)			-0.00047					**0.0006****	
			(0.00029)					(0.00024)	
Precipitation anomalies (mean past 3years; % value wrt mean 1961-1990)				-0.302					-0.263
				(0.331)					(0.373)
Temperature (mean past 3years; absolute value in ℃)					0.0339				
					(0.0908)				
Temperature anomalies (mean past 3years; absolute value in ℃)						0.0985		**0.258****	
						(0.0933)		(0.104)	
Temperature anomalies (mean past 3years; % value wrt mean 1961-1990)							0.00622		0.00780
							(0.0055)		(0.00542)
Precipitation * Temperature anomalies (mean past 3years; absolute value in mm)								**-0.0022 *****	
								(0.00059)	
Precipitation * Temperature anomalies (mean past 3years; % value wrt mean 1961-1990)									-0.0127
									(0.0349)
Constant	8.184***	6.547***	6.576***	6.545***	6.023***	6.455***	6.436***	6.465***	6.515***
	(1.389)	(1.359)	(1.337)	(1.342)	(1.648)	(1.367)	(1.377)	(1.349)	(1.344)
Observations	15,021	7,598	7,598	7,598	7,598	7,598	7,598	7,598	7,598
R-squared	0.846	0.837	0.837	0.837	0.837	0.837	0.837	0.838	0.837

Note: dependent variable ln(migration flows ij +1)t. Regressions include origin country fixed effects and 286 (26x11) destination-country-by-year fixed effects. Robust standard errors clustered by country of destination in parentheses. Observations are weighted by the population of destination countries. *** p<0.01, ** p<0.05, * p<0.1

Estimation results for the non-climatic covariates are in line with expectations. The size of bilateral migration flows is decreasing in the GDP per capita of origin countries; our proxy for the country of origin level of development. The larger is the difference in employment rate between origin and destination countries the larger is bilateral migration. A negative coefficient is associated with the variable capturing improvement in irrigated agricultural land; this variable captures the investment efforts undertaken by private and public agents in the agricultural sector which plays a crucial role in most of the origin countries included in our sample. As highlighted in previous studies (Pedersen et al 2008), migration networks play a crucial role in channelling immigration flows; in our baseline model the bilateral stock of already established migrants is the strongest determinant of subsequent bilateral flows. Distance is negatively associated with the size of the flows, while a common language between origin and destination countries has a positive effects on immigration flows.

We firstly proceed with the inclusion in the baseline model of simple measures of climate variability – precipitation and temperature anomalies with respect to the long term mean in absolute and percentage values[17]. The results reported in Table 3.1 suggest that there is no statistically significant relationship between climate anomalies in the origin country and international outmigration flows. Note that the joint inclusion in the baseline model of both temperature and precipitation anomalies in absolute values occurred in the previous 3 years (*Mod 1 PREC/TEMP*) and their interaction shows that climatic anomalies are significantly associated with larger migration flows; the estimated coefficient on the interaction effect suggests a mitigation effects if anomalies occurs jointly (i.e. when an increase in temperature is associated with an increase in precipitation).

As remarked above, the possibility of individuals to rely on a network of family and friends who reside in other locations (migration networks) might greatly affect their choices in terms of adaptation strategy to changes in climatic conditions. The results reported in Table 3.2 suggests that temperature anomalies occurred in the past 3 (or 5) years are significantly associated with higher migration flows but the existence of dense bilateral network of already established migrants seems to mitigate the effect.

Table 3.2 – Temperature anomalies and international migration: the role of migrant networks

Dependent variable:	**(4)**	**(5)**	**(4 bis)**	**(5 bis)**	**(6)**	**(7)**
Bilateral migration flows ij (in log)	TEMP	TEMP	TEMP	TEMP	TEMP	TEMP
GDP per capita i (lag 1; ln)	-0.304***	-0.302***	-0.272***	-0.270***	-0.292***	-0.303***
	(0.0892)	(0.0876)	(0.0858)	(0.0837)	(0.0999)	(0.105)
Employment rate difference ij (lag 1)	0.0261*	0.0262*	0.0301**	0.0301**	0.0249*	0.0245*
	(0.0132)	(0.0130)	(0.0127)	(0.0121)	(0.0136)	(0.0135)

[17] In Table 3.1 we report only estimates for climatic variable specified as averages for the 3 years before the observed migration flows. Estimates for 1-year and 5-years lagged climate anomalies have been computed and provide qualitatively similar results (available from the authors upon request).

Irrigated land % i (change btw lag 2 - lag 1)	-0.0114	-0.0159	-0.0222	-0.0399	-0.00852	-0.0103
	(0.123)	(0.123)	(0.126)	(0.120)	(0.126)	(0.125)
Network migrants ij (1990s; ln)	0.627***	0.633***	0.674***	0.698***	0.608***	0.608***
	(0.0352)	(0.0344)	(0.0312)	(0.0303)	(0.0372)	(0.0372)
Distance ij (ln)	-0.334**	-0.326**	-0.276*	-0.245	-0.356**	-0.356**
	(0.148)	(0.149)	(0.158)	(0.160)	(0.148)	(0.148)
Common language (dummy)	0.485***	0.477***	0.432***	0.403***	0.511***	0.511***
	(0.141)	(0.140)	(0.138)	(0.134)	(0.146)	(0.146)
Temperature anomalies (mean past 3years; % value wrt mean 1961-1990)	**0.0205*** **		**0.0659** **		0.0294	
	(0.00636)		(0.0248)		(0.0254)	
Temperature anomalies (mean past 3years; % value wrt mean 1961-1990) * **Network migrants ij**	**-0.0036*** **		**-0.0133*** **			
	(0.00095)		(0.00346)			
Temperature anomalies (mean past 3years; % value wrt mean 1961-1990) * **GDP per capita i** (lag 1; ln)					-0.00386	
					(0.00373)	
Temperature anomalies (mean past 5years; % value wrt mean 1961-1990)		**0.0277*** **		**0.0902** **		0.0224
		(0.00835)		(0.0377)		(0.0411)
Temperature anomalies (mean past 5years; % value wrt mean 1961-1990) * **Network migrants ij**		**-0.005*** **		**-0.0194*** **		
		(0.00137)		(0.00411)		
Temperature anomalies (mean past 5years; % value wrt mean 1961-1990) * **GDP per capita i** (lag 1; ln)						-0.00231
						(0.00687)
Temperature anomalies (mean past 3years; % value wrt mean 1961-1990) (**squared**)			**-0.00022** **			
			(8.76e-05)			
Temperature anomalies (mean past 3years; % value wrt mean 1961-1990) (**squared**) * **Network migrants** ij (1990s; ln)			**6.17e-05*** **			
			(2.03e-05)			
Temperature anomalies (mean past 5years; % value wrt mean 1961-1990) (**squared**)				**-0.00038** **		
				(0.000158)		
Temperature anomalies (mean past 5years; % value wrt mean 1961-1990) (**squared**) * **Network migrants** ij (1990s; ln)				**0.00011*** **		
				(2.93e-05)		
Constant	6.019***	5.905***	5.019***	4.564***	6.279***	6.334***
	(1.375)	(1.376)	(1.478)	(1.508)	(1.422)	(1.440)
Observations	7,598	7,598	7,598	7,598	7,598	7,598
R-squared	0.839	0.839	0.840	0.842	0.837	0.837

Note: dependent variable ln(migration flows ij +1)t. Regressions include origin country fixed effects and 286 (26x11) destination-country-by-year fixed effects. Robust standard errors clustered by country of destination in parentheses. Observations are weighted by the population of destination countries. *** p<0.01, ** p<0.05, * p<0.1

This results might be due to the "insurance" effects played by migrant networks through remittances (as in Yang and Choi 2007). We find evidence of non-linear effects: for example, using estimates from *model (4bis)*, a network which is 1% larger that the mean value of our sample implies that the average temperature anomaly (approx. 5%) leads to a bilateral out-migration flow which is 4% larger.

While the effects of temperature anomalies do not seems to depend on the relative level of development (as proxied by GDP per capita in the origin country; see model 6 and 7 in Table 3.2); precipitation anomalies represents a push factor of bilateral migration flows only in poor countries (Table 3.3).

Table 3.3 – Precipitation anomalies and international migration: the role of the level of development

Dependent variable:	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Bilateral migration flows ij (in log)	PREC	PREC	PREC	PREC	PREC
GDP per capita i (lag 1; ln)	-0.304***	-0.253***	-0.322***	-0.337***	-0.325***
	(0.0867)	(0.0890)	(0.0891)	(0.0864)	(0.0887)
Employment rate difference ij (lag 1)	0.0232*	0.0233*	0.0260*	0.0251*	0.0253*
	(0.0134)	(0.0132)	(0.0135)	(0.0135)	(0.0131)
Irrigated land % i (change btw lag 2 - lag 1)	-0.0290	-0.0277	0.381**	0.339	0.303
	(0.127)	(0.128)	(0.158)	(0.231)	(0.233)
Network migrants ij (1990s; ln)	0.608***	0.608***	0.608***	0.608***	0.608***
	(0.0374)	(0.0373)	(0.0373)	(0.0374)	(0.0373)

Distance ij (ln)	-0.356** (0.148)	-0.355** (0.148)	-0.357** (0.148)	-0.356** (0.148)	-0.356** (0.148)
Common language (dummy)	0.512*** (0.146)	0.513*** (0.146)	0.510*** (0.146)	0.510*** (0.146)	0.510*** (0.146)
Precipitation anomalies (mean past 3years; absolute value in mm)	**0.00237*** (0.00119)			-0.000392 (0.000309)	
Precipitation anomalies (mean past 3years; absolute value in mm) * GDP per capita i (lag 1; ln)	**-0.000398**** (0.000160)				
Precipitation anomalies (mean past 5years; absolute value in mm)		**0.00599***** (0.00120)			-0.000256 (0.000343)
Precipitation anomalies (mean past 5years; absolute value in mm) * GDP per capita i (lag 1; ln)		**-0.000890***** (0.000182)			
Precipitation anomalies (mean past 3years; abs value in mm) * change in irrigated land i (% lag 2 - lag 1)				**-0.00471**** (0.00197)	
Precipitation anomalies (mean past 5years; abs value in mm) * change in irrigated land i (% lag 2 - lag 1)					**-0.00412*** (0.00231)
Constant	6.343*** (1.357)	6.031*** (1.391)	6.458*** (1.348)	6.530*** (1.333)	6.478*** (1.360)
Observations	7,598	7,598	7,598	7,598	7,598
R-squared	0.838	0.838	0.837	0.838	0.837

Note: dependent variable ln(migration flows ij +1)t. Regressions include origin country fixed effects and 286 (26x11) destination-country-by-year fixed effects. Robust standard errors clustered by country of destination in parentheses. Observations are weighted by the population of destination countries. *** p<0.01, ** p<0.05, * p<0.1

In our analysis the threshold of GDP per capita below which anomalies are positively associated with migration outflows is approximately 1700 current US dollars (which includes most African countries and large countries such as China, Philippines). The outmigration-impact of large precipitation anomalies is – as one should intuitively expect – larger for countries which mostly rely on rain-fed agriculture (Table 3.3, last two columns).

The results highlighted so far are based on the assumption of a symmetric effects of climate anomalies of different sign (positive and negative). It is hard to believe that, for instance, a 20% contraction of annual rain will produce the same aggregate effects of a 20% increase of yearly precipitation in a poor country where agriculture is rain-fed. Our next step is to consider explicitly the potentially different effects of climate anomalies of different sign[18]. The results are presented in Table 3.4[19].

Table 3.4 – Climate anomalies and international migration: positive vs. negative shocks

Dependent variable: Bilateral migration flows ij (in log)	**(8)** TEMP	**(9)** TEMP	**(9)** PREC

[18] To our knowledge this is the first study which explicitly considers the asymmetric effect of positive versus negative temperature and precipitation anomalies.

[19] For the sake of space we present only estimations where climate anomalies are specified as 3-years average (lagged) expressed in % with respect to each origin country's 1961-1990 mean. Results for 1-year lagged anomalies and for 5-years averages are (qualitatively) consistent with those showed in *Table 3.4* and are available from the authors upon request.

GDP per capita i (lag 1; ln)	-0.313*** (.089)	-0.279*** (.010)	-0.331*** (.087)
Employment rate difference ij (lag 1)	0.0288** (.013)	0.0263* (.0137)	0.0249* (.0134)
Irrigated land % i (change btw lag 2 - lag 1)	-0.0320 (.123)	-0.0106 (.126)	1.10e-05 (.132)
Network migrants ij (1990s; ln)	0.676*** (.032)	0.608*** (.0374)	0.591*** (.0404)
Distance ij (ln)	-0.268 (.159)	-0.355** (.148)	-0.358** (.147)
Common language (dummy)	0.427*** (.139)	0.509*** (.146)	0.503*** (.146)
Positive temperature anomalies (mean past 3years; % value wrt mean 1961-1990)	**0.0615***** (.015)	**0.0604*** (.034)	
Negative temperature anomalies (mean past 3years; % value wrt mean 1961-1990)	**0.162**** (.0735)	**0.284*** (.144)	
Positive temperature anomalies (mean past 3years; %) * Network migrants ij	**-.0121***** (.003)		
Negative temperature anomalies (mean past 3years; %) * Network migrants ij	**-.0252**** (.009)		
Positive temperature anomalies (mean past 3years; %) * GDP pc i (lag 1; ln)		**-0.0094*** (.0048)	
Negative temperature anomalies (mean past 3years; %) * GDP pc i (lag 1; ln)		**-0.0386*** (.0210)	
Positive precipitation anomalies (mean past 3years; %)			-0.174 (.505)
Negative precipitation anomalies (mean past 3years; %)			**-2.352**** (1.037)
Positive precipitation anomalies (mean past 3years; %) * Network migrants ij			-0.0538 (.0805)
Negative precipitation anomalies (mean past 3years; %) * Network migrants ij			**0.368*** (.179)
Constant	5.120*** (1.471)	6.178*** (1.381)	6.602*** (1.326)
Observations	7,598	7,598	7,598
R-squared	0.840	0.838	0.838

Note: dependent variable ln(migration flows ij +1)t. Regressions include origin country fixed effects and 286 (26x11) destination-country-by-year fixed effects. Robust standard errors clustered by country of destination in parentheses. Observations are weighted by the population of destination countries. *** p<0.01, ** p<0.05, * p<0.1

It is interesting to notice that negative temperature anomalies have larger impacts on out-migration than positive temperature anomalies. Previous results on the "mitigation" effects of established migrant networks on bilateral outflows are confirmed. The size of climate-induced outflows - when we consider temperature anomalies - is decreasing in GDP per capita of origin countries; this result seems to confirm the hypothesis that population of less developed areas are more likely to cope with climatic shocks by adopting relocation strategies.

With respect to precipitation anomalies (column *9 Prec*), we find that shocks are significantly associated with outmigration only when they have a negative sign. Interestingly, negative precipitation anomalies induce more international migration in origin countries that have larger networks of established migrants – i.e. international migration is "channelled" through existing bilateral migration corridors. This result is in line with case studies (for instance McLeman et al 2008) that show that migration is a feasible and affordable adaptation strategy almost exclusively when individual have already established ties – family and friends ready to assist them - in other locations. The important corollary of this empirical evidence is the fact that it is likely that future climate-induced migration flows will follow "beaten paths" rather than create new ones.

Finally, we analyze the impact on bilateral outmigration flows of extreme climate events occurring in the past 3 or 5 years in the country of origin (Table 3.5)[20].

Table 3.5 – Extreme climate anomalies and international migration

Dependent variable: Bilateral migration flows ij (in log)	**(10)** PREC	**(11)** PREC	**(12)** PREC	**(13)** PREC	**(14)** PREC	**(10)** TEMP	**(11)** TEMP	**(12)** TEMP
GDP per capita i (lag 1; ln)	-.32*** (.090)	-.32*** (.091)	-.32*** (.090)	-.32*** (.090)	-.32*** (.084)	-.314*** (.089)	-.32*** (.089)	-.27*** (.089)
Employment rate difference ij (lag 1)	.0256* (.0135)	.0247* (.0132)	.0260* (.0134)	.0232* (.0133)	.0258* (.0136)	.0227* (.0131)	.0224* (.0130)	.0243* (.0133)
Irrigated land % i (change btw lag 2 - lag 1)	-.0201 (.127)	-.0187 (.127)	-.0214 (.127)	-.0292 (.123)	-.0106 (.129)	-.00609 (.130)	-.0179 (.127)	-.0222 (.127)
Network migrants ij (1990s; ln)	.608*** (.0373)	.608*** (.0373)	.608*** (.0373)	.616*** (.0369)	.602*** (.0375)	.564*** (.0392)	.568*** (.0397)	.608*** (.0373)
Distance ij (ln)	-.357** (.148)	-.356** (.148)	-.357** (.148)	-.353** (.147)	-.358** (.148)	-.352** (.148)	-.350** (.148)	-.356** (.148)
Common language (dummy)	.510*** (.146)	.511*** (.146)	.510*** (.146)	.506*** (.146)	.507*** (.146)	.512*** (.146)	.511*** (.146)	.512*** (.146)
<u>**Precipitation**</u>								
Extreme precipitation anomalies (above 90th percentile or below 10th percentile; average last 5 years; dummy)	**- .178**** (.082)							
Extreme positive precipitation anomalies (above 90th percentile; average last 5 years; dummy)		.00943 (.218)						
Extreme negative precipitation anomalies (below 10th percentile; average last 5 years; dummy)			**- .226**** (.097)					
Extreme positive precipitation anomalies (above 90th percentile; cumulated abs values in the last 3 years; dummy)				**.217**** (.091)				
Extreme positive precipitation anomalies (above 90th percentile; cumulated abs values in the last 3 years; dummy) * Network migrants ij (1990s; ln)				**- .040**** (.017)				
Extreme negative precipitation anomalies (below 10th percentile; cumulated abs values in the last 3 years; dummy)					**- .181*** (.093)			
Extreme negative precipitation anomalies (below 10th percentile; cumulated abs values in the last 3 years; dummy) * Network migrants ij (1990s; ln)					**.0304**** (.014)			
<u>**Temperature**</u>								
Extreme temperature anomalies (above or below 1 StDev; cumulated abs values in the last 3 years; dummy)						**- .308**** (.146)		
Extreme temperature anomalies (above or below 1 StDev; cumulated abs values in the last 3 years; dummy) * Network migrants ij (1990s; ln)						**.0503***** (.018)		
Extreme temperature anomalies (above 90th percentile or below 10th percentile; cumulated abs values in the last 3 years; dummy)							**- .299*** (.155)	
Extreme temperature anomalies (above 90th percentile or below 10th percentile; cumulated abs values in the last 3 years; dummy) * Network migrants ij (1990s; ln)							**.0465**** (.019)	
Extreme temperature anomalies (above 90th percentile or below 10th percentile; cumulated abs values in the last 5 years; dummy)								**.422*** (.241)
Extreme temperature anomalies (above 90th percentile or below 10th percentile; cumulated abs values in the last 5 years; dummy) * GDP per capita i (lag 1; ln)								**- .0567*** (.032)
Constant	6.45*** (1.366)	6.46*** (1.368)	6.45*** (1.367)	6.36*** (1.361)	6.46*** (1.355)	6.66*** (1.355)	6.66*** (1.355)	6.04*** (1.439)
Observations	7,598	7,598	7,598	7,598	7,598	7,598	7,598	7,598

[20] As a robustness check we define alternative thresholds levels (standard deviation, 80th / 20th percentiles) and consider extreme anomalies occurring only in the year before migration flows observed. These additional estimations are available upon request.

R-squared	0.837	0.837	0.837	0.838	0.838	0.838	0.838	0.837

Note: dependent variable ln(migration flows ij +1)t. Regressions include origin country fixed effects and 286 (26x11) destination-country-by-year fixed effects. Robust standard errors clustered by country of destination in parentheses. Observations are weighted by the population of destination countries. *** p<0.01, ** p<0.05, * p<0.1

Our climatic variable is specified as a dummy which is equal to 1 if the average precipitation (temperature), in the past 3 (or 5) years before the bilateral outmigration flow is registered, is above the 90^{th} or below the 10^{th} percentiles of the country of origin distribution of average yearly precipitation (temperature) in the last 4 decades. Let consider first extreme events related to average yearly rainfall. Model 10 shows that anomalies in the past 5 years which falls in the tails of the country of origin distribution are associated with reduced outmigration flows. This result is entirely driven by the left-hand-side tail of the distribution – i.e. extreme negative precipitation anomalies - as confirmed by model 11 and model 12. The role played by migrant networks is fundamental and (interestingly) different according to the kind of precipitation shock experienced by the origin country. Positive precipitation anomalies above the 90^{th} percentile (floods for instance) represent a strong determinant of bilateral outmigration flows but not in the presence of dense migration networks. On the contrary, in case of extreme negative precipitation anomalies migrant networks seems to "bridge" new international migration. A similar result is obtained when we consider extreme temperature anomalies - both for positive and negative shocks. This difference in the role that migration networks play in boosting or mitigating climate-induced migration might depend on their different economic and social impacts – for instance on vulnerable rural communities – or differences in the way such extreme shocks are perceived – temporary or persistent changes to local climate. A deep understanding of these interesting differences can be better acquired in our opinion through case studies and other qualitative methodological approaches. This complex role of networks emerges also from a comparison of studies based on individual sample surveys (see Piguet 2010 for a recent survey).[21]

[21] A recent case study on Bangladesh (Paul 2005) based on household surveys in tornado-affected communities finds evidence against climate induced outmigration. Evidence based on a sample of 739 rural household in El Salvador (Halliday 2006), a country with large international migrant's network, finds a positive relationship between climate shocks and migration. Analogous results are found by Munshi (2003) for outmigration from Mexican provinces to the US.

4. Conclusive remarks

In the past few years, media have often launched apocalyptic figures on migration flows that will be soon induced by the predicted changes in climatic conditions. Some of these figures were taken, often acritically, from important reports such as the Stern review (where between 150 to 200 million environmental refugees are forecasted in the next 30 years, a conservative assumption according to the authors) or other studies such as Christian Aid (2007). These estimates are often based on simplistic assumptions and what they actually measure is 'population at risk' (for instance resident in coastal floodplains at less than 1 meter of elevation) rather than actual migrants. In fact, these estimates do not consider other forms of adaptation strategies and in particular do not consider how eventually relocation of population affected by climatic changes will take place.

In this paper we highlights some important aspects of the complex links between climatic changes and human migration. Whether or not migration is the adaptation strategies followed by affected individuals and their families depends on several features related to (i) climatic shocks (types, magnitude, signs, duration etc.), (ii) characteristics of the affected population (for instance household resource endowments before and/or after climatic shocks), (ii) institutions (local, national and international ability to prevent / limit the adverse effects of climatic shocks).

The complexity of the links implies that our knowledge on this issue relies on the ability to pool results and information using different lenses (i.e. from different methodological approaches). We provide results employing a "macro" approach and looking at the relevance of climatic anomalies of different nature as determinant of international bilateral migration flows. Our results show that climate anomalies are positively related to international migration but it is fundamental to consider the type of changes (negative versus positive shocks to precipitation and temperature) and where they happen (relatively poorer or richer countries / irrigated or rain-fed agricultural systems). We find evidence of an important and ambiguous role played by network of migrants in potential destination country. In some cases – such as negative precipitation anomalies and large temperature anomalies – networks seems to incurage more outmigration while in other cases – for instance large positive precipitation anomalies – we find opposite results.